Technology Opportunity

Generating Models for Control System Design from Steady-State Computational Fluid Dynamics Results

The National Aeronautics and Space Administration (NASA) seeks to transfer technology that will make it easier to design controls for systems that can be modeled by CFD codes.

Potential Commercial Uses

- Design and validation of control systems for anything that can be modeled by a CFD code

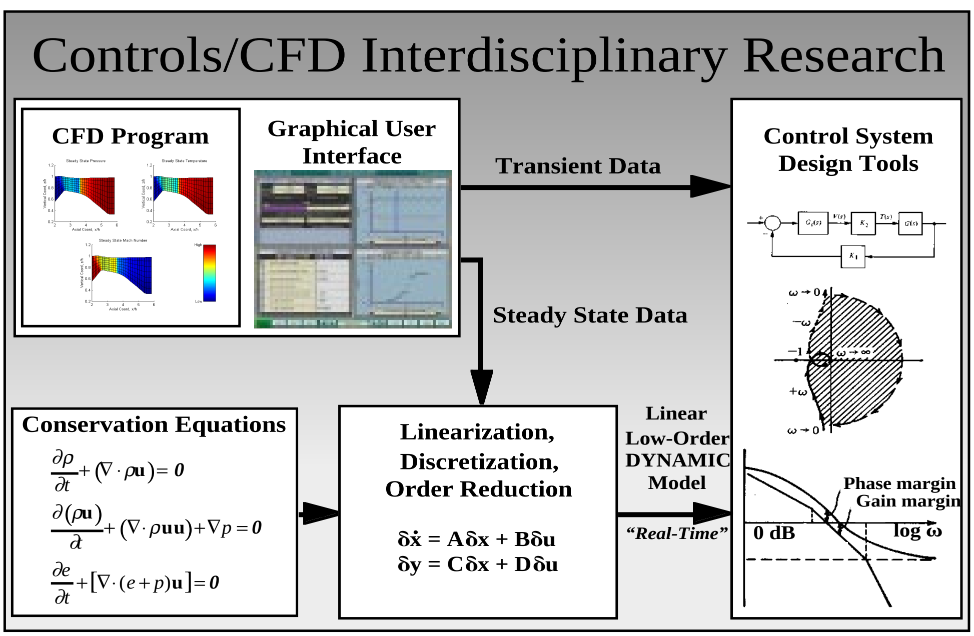
Benefits

- Reduced time and cost for control system design and validation
- Improved model accuracy yields improved initial control
- More structured/consistent approach for developing plant models

The Technology

The design of propulsion controls for complex vehicles relies on accurate models of the system components. Control design engineers typically use time-dependent linear models to represent a plant during the initial stages of control development. The linear models are often obtained from simplified, nonlinear lumped-parameter simulations. Computational fluid dynamics (CFD) is an alternative modeling technology that provides a highly accurate nonlinear solution. These high-resolution, multidimensional simulations are often generated as part of the design process. However, control engineers seldom, if ever, use CFD models because such models often lack the necessary time-accurate capabilities, have extraordinarily long execution times, and are difficult to set up and use.

NASA Lewis Research Center is developing analytical and computational tools that will enable controls engineers to routinely use CFD technology. If CFD simulations were able to generate high-fidelity plant models for use in control system design, the time and cost required to develop propulsion system controls would be reduced. An interdisciplinary team with expertise in three key areas—CFD



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computational technology, controls-CFD interface technology, and model generation for control system design and analysis—is working toward this end. The three technologies are described herein, and the accompanying figure shows the approach this research is taking to integrate them. The technology will initially be applied to the High Speed Civil Transport (HSCT) inlet control problem, but the techniques developed will be applicable to other propulsion system components and, perhaps, to other engineering disciplines.

CFD computational technology. This work has two main objectives: to develop CFD codes that provide an accurate representation of the dynamics of high speed inlets; and to evolve CFD to the point where it can be used as a "numerical test bed" for preliminary control validation (i.e., use CFD instead of an experiment). NPARC, a multidimensional Navier-Stokes code, is currently being modified to include dynamic subcomponent models required by propulsion control engineers. Modifications have already been made that provide time-accurate operation and realistic boundary conditions. And transient calculations are being performed to demonstrate its use as a numerical test bed. Soon it will also be able to accommodate moving geometry. These time-consuming calculations are driving the effort to use parallel and distributed processing techniques to reduce execution time.

Controls-CFD interface technology. A controls-CFD interface is being designed to make it possible for a non-CFD- expert to operate the CFD simulation as though it were a numerical "experiment." The first-generation interface design is based on a custom-designed multiprocess operating environment. It has been implemented by using a distributed computing approach. An easily modified text file defines the desired operating system functions and data base requirements. Typical operating system functions provided include interactive execution of the simulation, run-time monitoring of key simulation variables, and data base management of resulting calculations and associated information. CFD results saved in the data base are currently postprocessed outside of the interface. They are converted to files of information/data-structures that can be used with custom-designed and commercial controls analysis tools to generate the desired (reduced order) linear models. A first-generation interface prototype has been demonstrated. Development of a second-generation interface is under way. The interface is used to forward data to analysis programs in one of two forms—steady-state or transient. The steady-state data can be used to generate linear models for control system design and the transient data can be used to validate the linear models.

Model generation technology. The objective of this portion of the research is to generate low-order, time-dependent linear models from steady-state CFD results. CFD simulations are generally very time-consuming and, as such, are not practical tools for control design. However, a set of equations exists that is the essence of the CFD simulation. These equations have been linearized about the steady-state point obtained from CFD, thus yielding a set of matrices that describe a time-dependent linear model. Order reduction techniques are then used to reduce the size of the large models resulting from the linearization process. The techniques may reduce the model order by as much as 99 percent while still capturing most of the relevant physics and greatly reducing computational requirements. In so doing, they provide the control engineer with an accurate, efficient, and familiar model for design and analysis purposes.

Options for Commercialization

NASA Lewis Research Center is interested in partnering with industry to transfer all or part of this technology to the commercial sector.

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Key Words

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